Implementing Integrated Services of Networked Home Appliances Using Service Oriented Architecture

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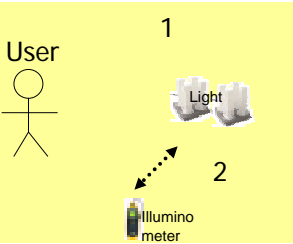

Home Network System HNS [1][2][3][4]

- HNS is a system consisting of several networked home appliances and adds more value to the daily life.

- The appliances in HNS are controlled together to provide integrated services.
  - DVD, TV, Lights, Air Conditioner, Thermometer, etc.

[1]DLNA (2004) Digital Living Network Alliance [Online] Available: http://www.dlna.org/ [2004].
[2]ECHONET (2004) ECHONET CONSORTIUM [ONLINE] Available: http://www.echonet.gr.jp/english/ index.htm [2004].
[3]Hitachi. (2004) Horaso Network Service [ONLINE] Available: http://ns.horaso.com/ [2004].
[4]LG.E.. (2004) Home Network. [ONLINE] Available: http://www.lge.com/products/homenetwork/homenetwork.jsp

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HNS Integrated Services
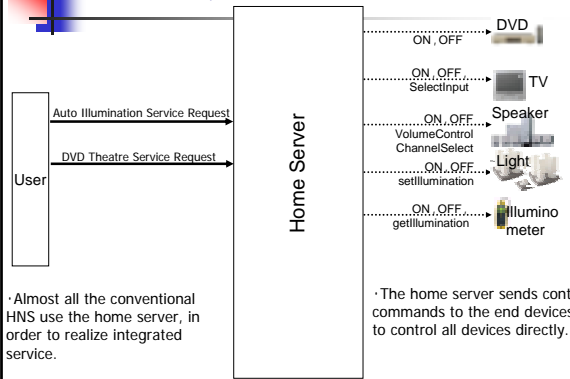
Auto-illumination Service

1. User turns on the Light
2. Light adjusts its brightness to optimal based on the current illumination.
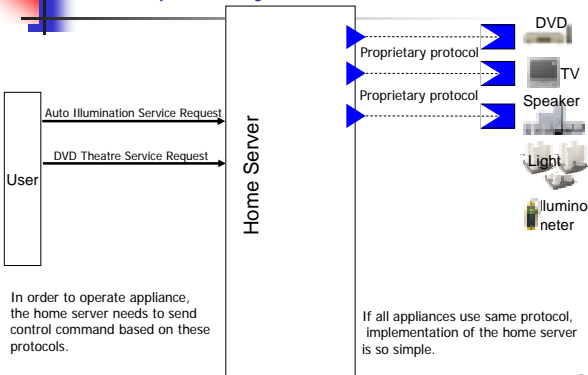
DVD Theatre Service

1. User turns on the DVD
2. TV is turned on and Speaker Channel is set as DVD-mode
3. Light becomes dark, adjusted based on illuminometer

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Conventional HNS(Server Centralized Architecture)

Almost all the conventional HNS use the home server, in order to realize integrated service.

The home server sends control commands to the end devices to control all devices directly.

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Problems on the conventional HNS :Interoperability(1/4)

In order to operate appliance, the home server needs to send control command based on these protocols.

If all appliances use same protocol, implementation of the home server is so simple.

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Problems on the conventional HNS :Interoperability(1/4)

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Problems on the conventional HNS :System Extention(2/4)

User

Auto Illumination Service Request
DVD Theatre Service Request
Auto Temperature Control Service
Coming Home Service

Home Server

Gateway Mechanism

Proprietary protocol
Proprietary protocol

DVD
TV
Speaker
Light
Illumino neter
Door
AC
Thermo meter

In HNS User may add or modify the contents of integrated services and appliance environment.

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Problems on the conventional HNS :Load Concentration(3/4)

User

Auto Illumination Service Request
DVD Theatre Service Request
Auto Temperature Control Service
Coming Home Service

Home Server

Gateway Mechanism

Proprietary protocol
Proprietary protocol

DVD
TV
Speaker
Light
Illumino neter
Door
AC
Thermo meter

Every Integrated services needs the Home Server
The number of appliances reflects heavy workload of the server.

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Problems on the conventional HNS :Reliability(4/4)

User

Auto Illumination Service Request
DVD Theatre Service Request
Auto Temperature Control Service
Coming Home Service

Home Server

Gateway Mechanism

Crash

Proprietary protocol
Proprietary protocol

DVD
TV
Speaker
Light
Illumino neter
Door
AC
Thermo meter

A crash of the server makes all the integrated services unavailable

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Research Goal

Goal
- Develop improved HNS
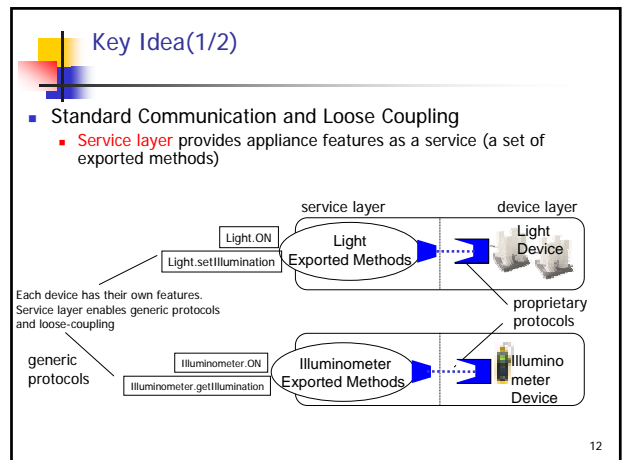 - Interoperability, Extendibility, Load-balancing, Reliability

Approach
- Design the SOA-based integrated services with concrete service scenarios
- Evaluate the integrated services with a graph-based method
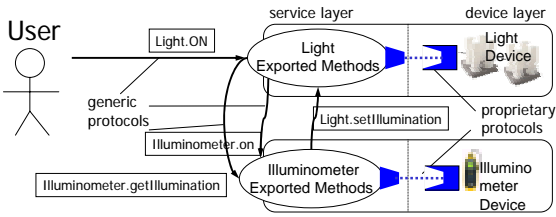
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Example Service Scenarios

- SS1: Auto Illumination Service
  - The brightness of the light is automatically adjusted based on the current intensity of illumination with the illuminometer.
- SS2:Coming Home Service
  - If the user enters a room from the door, the light are turned on.
- SS3: DVD Theatre Service
  - When the user turns on the DVD player, the light becomes dark. Then, the TV and the speaker start in the DVD mode.
- SS4: Auto-TV Service
  - When the user watches the TV, the speaker is turned on.
- SS5: Ringing and Mute Service
  - While the user is watching the TV, if the telephone rings, then the volume of the speaker becomes small.
- SS6: Auto Temperature Control Service
- SS7: Coming Home Service about Temperature
- SS8: Sleep Service

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Key Idea(1/2)

- Standard Communication and Loose Coupling
  - Service layer provides appliance features as a service (a set of exported methods)

service layer

device layer

Light.ON
Light.setIllumination

Light Exported Methods

Light Device

Each device has their own features.
Service layer enables generic protocols and loose-coupling

proprietary protocols

generic protocols

Illuminometer.ON
Illuminometer.getIllumination

Illuminometer Exported Methods
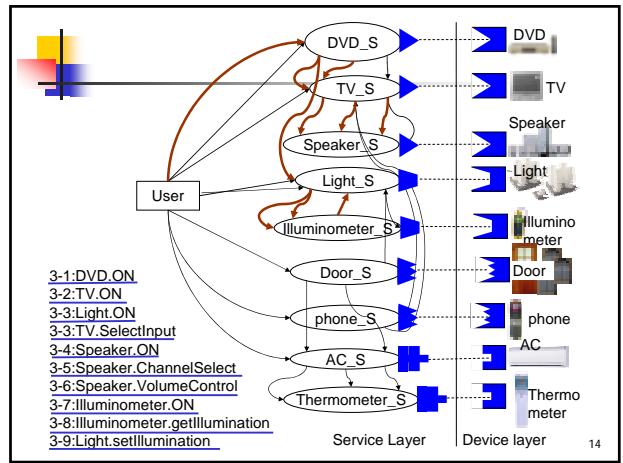
Illumino meter Device

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Key Idea(2/2)

- Autonomous Orchestration without server
  - Service Layer enables direct and autonomous communications among appliances without any centralized servers.

User

service layer

device layer

Light.ON

Light Exported Methods

Light Device

generic protocols

Light.setIllumination

proprietary protocols

Illuminometer.on

Illuminometer.getIllumination

Illuminometer Exported Methods

Illuminometer Device

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DVD_S → DVD
TV_S → TV
Speaker_S → Speaker
Light_S → Light
Illuminometer_S → Illuminometer
User
Door_S → Door
phone_S → phone
AC_S → AC
Thermometer_S → Thermometer

3-1:DVD.ON
3-2:TV.ON
3-3:Light.ON
3-3:TV.SelectInput
3-4:Speaker.ON
3-5:Speaker.ChannelSelect
3-6:Speaker.VolumeControl
3-7:Illuminometer.ON
3-8:Illuminometer.getIllumination
3-9:Light.setIllumination

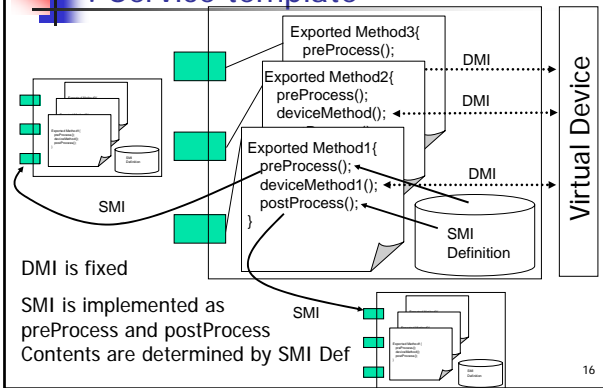Service Layer | Device layer

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Implementation of HNS prototype

- Service Layer
  - Java Web Service
    - Web server: Jakarta Tomcat 4.1.18
    - Apache-AXIS 1.1
    - Java2 SDK SE 1.4.1_02
- Device Layer
  - Virtual Device component
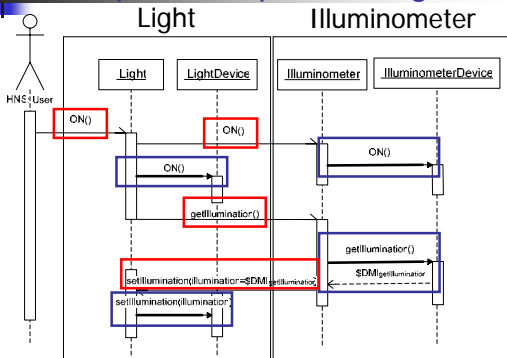   - Implemented with java beans
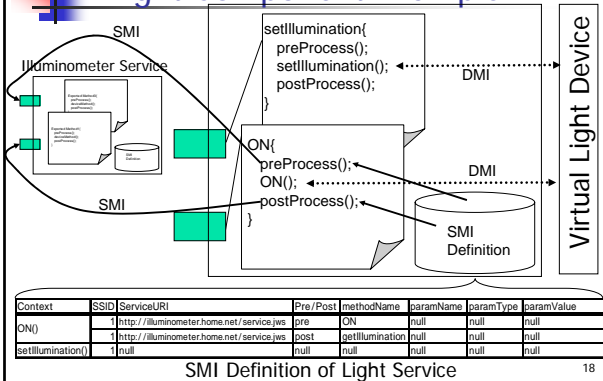
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Implementation : Service template

Exported Method3{
  preProcess();

Exported Method2{
  preProcess();
  deviceMethod();

Exported Method1{
  preProcess();
  deviceMethod1();
  postProcess();
}

DMI
DMI
DMI

Virtual Device

SMI
SMI Definition

DMI is fixed

SMI is implemented as preProcess and postProcess Contents are determined by SMI Def

SMI

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Example of Sequence diagram

Light | Illuminometer

HNS User

Light | LightDevice | Illuminometer | IlluminometerDevice

ON()
ON()
ON()
ON()
ON()
getIllumination()
getIllumination()
$DMIgetIllumination
setIllumination(illumination=$DMIsetIllumination
setIllumination(illumination)

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Implementation : Light Component Example

Illuminometer Service

setIllumination{
  preProcess();
  setIllumination();
  postProcess();
}

ON{
  preProcess();
  ON();
  postProcess();
}

DMI
DMI
DMI

SMI
SMI Definition

SMI

Virtual Light Device

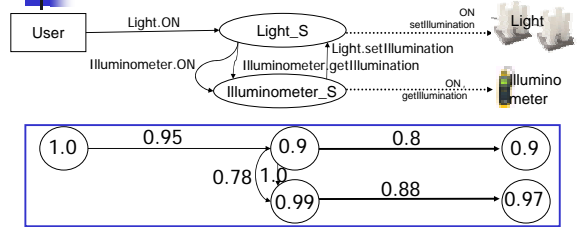| Context	SSID	ServiceURI	Pre/Post	methodName	paramName	paramType	paramValue
ON()	1	http://illuminometer.home.net/service.jws	pre	ON	null	null	null
	1	http://illuminometer.home.net/service.jws	post	getIllumination	null	null	null
setIllumination()	1	null	null	null	null	null	null

SMI Definition of Light Service

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Design metrics of HNS

- Reliability
- Workload
- Coupling

# n-reliability based on SDP Algorithm[7]

- Present each service scenario as a labeled directed graph
- For a given HNS with integrated service scenarios we define n-reliability as the probability that at least n service scenarios are operational in the HNS.
- Reliability of each node and edge are given, the SDP calculates reliability that at least one of specified set of service scenarios.

[7] T. Tsuchiya T. Kajikawa and T. Kikuno (2000) 'Parallelizing SDP (Sum of Disjoint Products) Algorithms for Fast Reliability Analysis' IEICE Transactions on Information and Systems Vol.E83-D No.5 May pp.1183-1186.

n-Reliability: Result
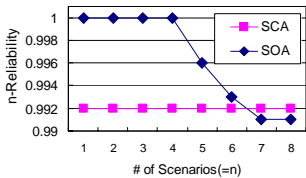
Reliability
each web service=0.999
Home Server=0.992 (=0.999^8)
(To evaluate the reliability relevant to the architectural differences, we don't consider any faults of other elements)

- n-reliability for SCA becomes equal to the reliability of the home server
- In SOA, the eight scenarios are executed by the distributed services. So higher fault tolerance than the SCA-based ones.
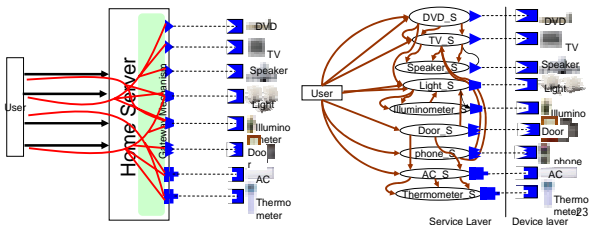
Other design metrics

- Workload
  - Usage frequency of the service scenarios
  - SOA-based HNS, it's relatively easy to perform flexible design changes reflecting the workload
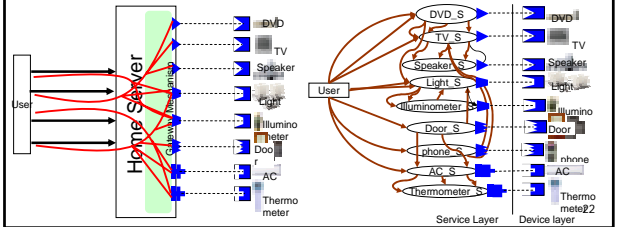
Other design metrics

- Coupling
  - Degree of dependence of a component against other components
  - Components in conventional HNS are heavily dependent on the HS, so the crash of Home Server is fatal.

Related Work

- BPEL4WS
  - Standard service orchestration framework
  - Creating new service integration with XML-based language definition
  - Needs a centralized server for orchestration
  - Takes over the same problems of conventional HNS

Discussion :Advantage

- Interoperability is improved
- Fault-tolerant and load-balanced
- Easily modifying and updating the integrated service

Discussion :Limitation

- Cost of Appliances
- Communication Overhead
- Global management

Future plan

- Detect and resolve feature interaction problem
  - FI problem occurs, since multiple users can activate multiple services simultaneously in the HNS.